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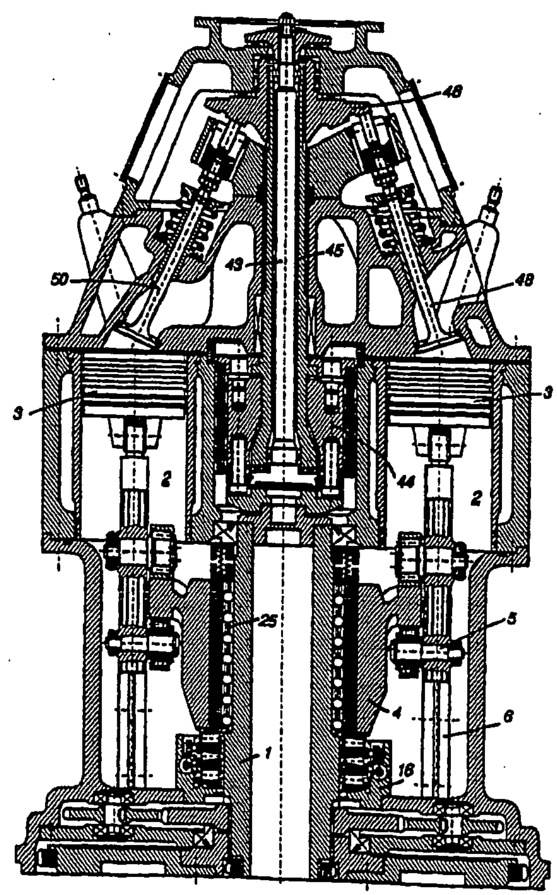
(54) Title: CAM ENGINE

(57) Abstract

The invention relates to a cam engine having specific cam curve, where each working profile of the cam (4) is performed with undulating configuration to insure the function for movement of the followers (5) continuous until at least its second derivative within one turnover of the cam (4). The engine may include a mechanism to change the compression ratio and mechanism regulating the fuel–air mixture distribution.



CAM ENGINE

FIELD OF THE INVENTION

The invention refers to a cam engine, used in engine construction. The engine can be used for building in different kinds of land, sea and air motor vehicles or in stationary units.

BACKGROUND OF THE INVENTION

One of the most important, but not always in common resolved problems regarding the engine construction, is to improve the efficiency of the engine to use completely the heat delivered to the cylinders and to achieve better equalizing and steadiness improving the reliability and the operation of the engine. There are cam internal combustion engines and Stirling-cycle machines, all comprising at least one axial cylinder, all cylinders located parallel to and equidistantly from the main shaft of the engine. Each cylinder is provided with a mobile piston, the rod of which is connected to cam surface of a drum by cam follower with possibility to move through the cam. The cam profile is constructed as a curve circumscribed according to a determined function. The cam is connected to the main shaft. Besides, the engine comprises means for delivering and/or removing the working substance, both connected with the combustion chambers of the engine. The cam engines, besides the simple construction, which can be executed symmetric to the axis, permit according to the function for movement of the cam followers through the drum cam simultaneously to influence in great extent over the thermodynamic cycle of the engine and to be achieved total equilibration regarding the inert forces.

There are cam engines of Stirling cycle with a swash plate /US 5343704/ or cam executed according to harmonic function /WO 82/04101 of Moscrip/. Here the process proceeds according to the thermodynamic cycles for this type of engines which results in reduction of the efficiency. Besides it is impossible to regulate the operating duty according to loading and can not be achieved improved equilibration and steadiness of the engine.

The cam internal-combustion engines are more popular. For example, it is known from US 4492188 cam internal-combustion engine of Palmer with cam executed according to sinus function. This function permits achievement of better equilibration and steadiness of the engine, but insures the work regarding only some of the popular thermodynamic cycles for gasoline or diesel engine. The cycles do not permit better use of the supplied heat, therefore the thermodynamic and efficiency coefficients are low.

There are also known other cam internal-combustion engines with cam being for example saw line with rectilinear asymmetric parts in view /US 4553508, Stinebaugh/, or cam with dead points in each axial direction at different levels /US 5140953/. It is possible cam curve which /US 5218933/ insures during compression to diminish sharply the velocity of the piston on ignition and after that to increase before reaching top dead center. All these curves

reliability. It is not provided a mechanism to displace the fuel-air mixture distribution phases. There are big losses from friction in the splined connection between the working shaft and the cam upon changing the compression ratio. The mechanism regulating the compression ratio enables the appearance of pulsation on movement of the cam through the working shaft, causing vibrations and noise with different amplitude and level for cold and warm engine.

SUMMARY OF THE INVENTION

The main object of the invention is to provide a cam engine with the highest efficiency, which is more economical and environmentally save.

It is a further object of the present invention to provide an improved cam engine which is maximum balanced and reliable and having improved wear resistance of exploitation. The level of noise and vibrations to be normal. The engine must operate without impacts.

It is another object of the present invention to provide an improved cam engine having better dynamic qualities.

It is another object of the present invention to provide an improved cam engine being effective at all operating duties, keeping optimal thermodynamic cycle, realizing the maximum possible efficiency for each operating duty of the engine.

It is another object of the present invention to provide an improved cam engine, which must be manufacturable for production and repair, with low specific amount of metal and low energy consumption for construction.

It is another object of the present invention to provide an improved cam engine, which should enable the building in different working machines.

The next object of the present invention is to provide an improved cam engine which permits the use of simple transmission and gives possibility for more functions.

It is another object of the present invention to provide an improved cam engine keeping the serviceability at higher working temperatures and temperature differences.

The above mentioned and other objects of the present invention have been achieved by a cam engine comprising working shaft and at least one axial cylinder, all cylinders located parallel to and equidistantly from the working shaft. Each cylinder has at least one piston with possibility of reciprocating movement in the cylinder, the said piston connected with a cam mechanism. The chambers of the cylinders can be connected with means for delivery and/or means for removal of the working substance. The cam mechanism comprises at least one cam drum connected coaxial with the working shaft and at least one cam follower with the possibility of reciprocating movement through guides. At least one of the followers is connected with a piston rod, forming a real piston cam follower. Each cam follower is in contact with the possibility of movement through at least one of the working profiles of the cam drum. Each profile of the cam is executed with undulating configuration according to a function, continuous until at least to its second derivative within the whole cam curve, so

Fig.4a and 4b show a graphic representation of the thermodynamic cycles corresponding to known four-stroke diesel engine and cam four-stroke diesel engine according to the invention;

Fig.5 shows a view of a mechanism of cam engine with one real piston cam follower;

Fig.6a and 6b are view and a cross section through the body of a cam follower and fig.6c is a view of a cage from the assembly of the cam follower and guide;

Fig.7a-d are cross sections of different embodiments for assembly of the cam follower and guides;

Fig.8 is a cam mechanism comprising two real piston followers and two simulating followers;

Fig.9a-d are schemes showing different ways of location of the cam followers round the cam drum;

Fig.10, fig.11 and fig.12 show views of cam mechanisms with different orientation of the real piston followers;

Fig.13a and fig.13b show a function and its second derivative of movement of the cam followers with rectilinear horizontal sectors in each top and bottom dead center and with rectilinear sectors in the middle of all ascending and descending branches of the curve;

Fig.14 is graphic representation of the difference in the level in axial direction for two contact surfaces from the working profile of the cam;

Fig.15 is schematic representation of contact coupling between a cam follower and the groove of the cam in top dead center;

Fig.16a-c show different ways for elastic suspension of the contact element from the cam follower;

Fig.17 shows a follower, enabled to work with cam having working flange;

Fig.18 shows the coupling between component cam with groove and contact elements of the cam follower;

Fig.19 is longitudinal section of mechanism changing the compression ratio;

Fig. 20a-d show different embodiments of the lifter of the mechanism from fig.19;

Fig.21a and 21b show cross sections of embodiments of the unit for axial displacement from the mechanism shown on fig.19;

Fig. 22a and 22b show embodiments of the splined unit for axial displacement;

Fig.23 is longitudinal section of engine with two working cams and two-side located piston-cylindrical groups;

Fig.24 and fig.25 are embodiments of mechanism insuring optimum tightening between the guides and the cam followers of the cam mechanism;

Fig.26a-d show a regulator of centrifugal type for mechanism to control the fuel-air mixture distribution according to fig.1, working with advance;

DETAILED DESCRIPTION OF THE INVENTION

Different engines can be realized according to the invention - internal-combustion four-stroke and two-stroke engines and external-combustion engines of Stirling type. The examples regarding the cam's curve will be given for internal-combustion four-stroke engines, but the analysis is valid also for two-stroke engines and the engines with Stirling cycle.

Fig. 1 shows one embodiment of four-stroke engine according to the invention. The engine comprises working shaft 1 and in this case more than one axial cylinders 2, located equidistant and steadily round the shaft 1. In each cylinder 2 with one-side or two-side operation, in this case with one-side operation, can be located depending on the operation at least one piston 3 with possibility for reciprocating movement. The pistons 3 of all cylinders 2 are joined with cam mechanism comprising a cam drum 4, connected with the shaft 1, this way is ensured possibility for mutual receipt and delivery of motions, forces and moments. The cam mechanism further comprises cam followers 5 contacting the cam 4 and guides 6 to guide the followers 5. The curve of the cam 4 has undulating configuration and ensures function for movement of the cam followers 5, which is continuous at least to its second derivative within the whole rotation interval from 0° to 360° of the cam 4. On movement of the followers 5 the velocity and the acceleration at the beginning and at the end of each ascending and descending sector from the period of the curve of the cam 4 are with equal value and the maximum and minimum values of the accelerations are located in the middle centers of each ascending and descending sector. This way are equaled the conditions on which effects the thermodynamic cycle in engine with two-side cam followers and relatively low values are received for the velocity of the cam followers 5 round each dead position. This thermodynamic cycle is especially effective for engines working with fast combustible air-fuel mixtures. Besides, the conditions improve to achieve the balance of the engine. Fig. 2 shows a function for movement of the cam followers 5 corresponding to the curve of the cam 4 where is possible the velocities and the accelerations of the followers 5 at the beginning and at the end of each ascending and descending sector from the period of the curve to be equal to zero. This way are achieved better conditions for effecting of the thermodynamic cycle with slower combustible fuels. It is shown that in each convexity from the curve can be provided rectilinear horizontal sector and on movement of each piston 3 to remain static in each top and/or bottom dead position. This insures improved conditions for operation of the thermodynamic cycle in all operating duties with the slowest combustible fuels. Besides, it insures constant volume of heat supplied to the combustion chamber and enough time for its assimilation, better ventilation of the working cylinders and charge with fresh working substance. The rectilinear horizontal sectors can be equal to each other which besides the improvements in the cycle, ensures the achievement of complete balance for the engine. When comparing fig. 4a and 4b show that with the cam engine according to the invention whose curve on the cam drum is realized according to the function on fig. 2 is increased in great

$$\beta + \frac{\delta}{2} \leq \varphi \leq 2\beta \qquad S(\varphi) = H - H\left[\frac{\varphi - \beta - \frac{\delta}{2}}{\gamma} - \frac{1}{2\pi}\sin\left(2\pi\frac{\varphi - \beta - \frac{\delta}{2}}{\gamma}\right)\right]$$

$$2\beta - \frac{\delta}{2} \leq \varphi \leq 2\beta \qquad S(\varphi) = 0,$$

for the third stroke, as follows:

$$2\beta \leq \varphi \leq 2\beta + \frac{\delta}{2} \qquad S(\varphi) = 0,$$

$$2\beta + \frac{\delta}{2} \leq \varphi \leq 3\beta - \frac{\delta}{2}$$

$$S(\varphi) = H - H\left[\frac{\varphi - 2\beta - \frac{\delta}{2}}{\gamma} - \frac{1}{2\pi}\sin\left(2\pi\frac{\varphi - 2\beta - \frac{\delta}{2}}{\gamma}\right)\right]$$

$$3\beta - \frac{\delta}{2} \leq \varphi \leq 3\beta \qquad S(\varphi) = H,$$

for the fourth stroke, as follows:

$$3\beta \leq \varphi \leq 3\beta + \frac{\delta}{2} \qquad S(\varphi) = H,$$

followers 12 and/or real piston followers 11, or units 5' are with equal mass and are located steadily round and equidistant from the axis of the cam drum 4. Besides, the convexities from the curve of the cam are steadily located round its axis. Besides on movement of the followers 5, the accelerations of the said followers 5, which are equidistant from the beginning of each ascending and descending sector from the period of the curve are with equal value and sign. For example on fig. 13 the acceleration a1 for the first follower is with equal value and direction as the acceleration a5, a2 is equal to a6 etc. It is preferably the profile of the cam 4 to be executed with even number of convexities, at least four and the number of cam followers 5 or units 5' to be even, not less than four. Besides, this number is preferably to be divisible to the number of the cam curve's convexities and half of the number of convexities to be odd number. Alternatively, half of the number of the cam curve convexities can be even number which is not divisible to the number of the followers 5. For example under six pieces of cam followers 5 have six pieces of convexities on the cam's profile or under four pieces of cam followers 5 have ten pieces of convexities. In this embodiment when the number of dead positions increases the turnovers of the engine diminish proportionally and the moment of rotation increase, the power remaining fixed. This insures the overall dimensions of the engine to satisfy the concrete needs. The number of parts in the engine can diminish, for example can be eliminated the necessity of reducer for the big ship engines. Besides, the curve of the cam can be executed in such a way that on movement of the followers 5 the maximum and minimum values of the accelerations of these followers 5 which are located equidistantly from the middle of each ascending and descending sector are nearer to the beginning and to the end of each sector than to its middle, so as the maximum and minimum value of the difference from the products of the first and the second derivative from the beginning and the middle of each sector as per function for movement is minimal. This way can be improved the balance of the cam engine if the number of the working cylinders is even and they are steadily located round the axis of the engine.

As shown on fig. 10 the engine according to the invention can work with double acting piston followers 11, each of them provided in its both ends with coaxial pistons 3 moving in coaxial cylinders 2, located opposite each other. As shown on fig. 11 all the pistons 3 can be one-side located. One combination of differently oriented one-side acting real piston followers 11 is shown on fig. 12 where each two adjacent pistons 3 are oriented in opposite directions. These versions of orientation of the pistons 3 give the possibility to be liberated bigger spaces round the cam 4, to build in additional aggregates and to diminish the number of parts and cross clearances of the engine, keeping its working volume.

In one embodiment of the invention, outlined in fig. 13a and 13b with the functions for movement of the followers 5, the profile of the cam 4 is executed in such a way that additionally in the middle of all ascending and descending sectors there are rectilinear inclined sectors and the accelerations of the cam followers 12 and/or 11 in these sectors are equal to

elastic suspended contact element 14' can be constructed with eccentricity with possibility for regulation. When the functions by which are produced the contact surfaces 13 and 13' are displaced one another towards the stroke of the cam follower 5, then the elastic element 15 must have the possibility to deform only within the difference of the stroke or the eccentricity e.

The cam engine can be provided with mechanism to change the compression ratio. On examining the embodiment shown on fig. 1 with one-side located piston-cylindrical groups and fig. 19, this mechanism comprises lifter 16, located coaxial to the shaft 1 under or above the cam 4. In one embodiment shown on fig. 19 the lifter 16 can include a body 17. To the internal face of the body 17 is attached coaxial thrust washer 18 without possibility of rotation against it and mounted on the face of the washer rolling elements 19 being in contact with one of the faces of coaxial controlling face cam 20. To compensate technological errors it is preferably the connection between the washer 18 and the body 17 to be executed as spherical bearing. The controlling cam 20 is in contact with driving elements 21 which in the shown embodiment are executed as hydraulic cylinders - toothed bars to set in motion the cam round the axis of the shaft 1. Over the other face of the controlling cam 20 are located rolling elements 22 which can be smooth /fig. 20d or 20e/ or profiled oval bodies /fig. 20a-c/. The rolling elements 22 contact one of the faces of the executive cam 23. Over the rolling elements 22 contacting the face surfaces of the controlling cam 20 and/or of the executive cam 23 can be performed equal wavelike concavities and convexities connected smoothly as shown on fig. 20 b-e. The executive cam 23 is insured against rotation towards the body 17 and can execute only coaxial motion. Over the other face of the cam 23 are located other rolling elements 24 contacting one of the faces of the working cam drum 4. The mechanism changing the compression ratio includes also a unit 25 for axial movement of the cam 4 /fig. 1, 19, 21a, 21b and 22/. The unit 25 comprises rolling elements 26 which can be with different shape, for example spheres /fig. 19b/ or rollers /fig. 19a/. The rolling elements 26 are located in cage connecting the shaft 1 and the cam 4 with formed longitudinal grooves 27. The grooves 27 can be parallel or inclined to the axis of the shaft 1 as shown on fig. 22. When the grooves 27 are inclined, additionally upon change of the compression ratio it is possible to influence the displacement of fuel-air mixture distributive phases. It is preferably to act elastic elements over the face of the cam 4, opposite to the lifter 16 for example tension springs 28, to eliminate the slippage upon movement of the working rolling elements 22 and the turning of the cam 4 in direction of diminishing the compression ratio. In other embodiment for mechanism regulating the compression ratio, especially suitable for building in of cam engine with two-side located piston-cylindrical groups, the engine comprises two working cams 4A and 4B as shown on fig. 23. There are two opposite acting and self-regulated mechanisms to control the compression ratio, located each one in the bottom of the corresponding cam. Each lifter 16A and 16B is executed as one-side acting hydraulic cylinder, whose piston 29 is

To stabilize the thermodynamic characteristics of the engine /fig. 1, 26-32/ it can be provided with a mechanism regulating the fuel-air mixture distribution with phase shift. It helps to establish optimum phases of fuel-air mixture distribution according to the changes in compression ratio and engine's turnovers. Commonly, the mechanism regulating the fuel-air mixture distribution comprises primary shaft 43, fixedly connected as prolongation of the working shaft 1. The primary shaft 43 can drive for example a fuel-injection pump, a current distributor etc. Through a regulator 44 coaxial to the primary shaft 43 is connected secondary hollow shaft 45 with possibility for axial and/or angle movement. A coaxial cam block of the fuel-air mixture distribution 46 is connected to the shaft 45 through splined connection. The cam block 46 comprises at least one cam profile 47 for the discharge valve 48 in case the engine is two-stroke. In case the engine is four-stroke the cam block 46 comprises two cam profiles and cam profile 49 for inlet valve 50. On fig. 1 and 26a-d is shown one embodiment for mechanism regulating the fuel-air mixture distribution with advancing phase shift of four-stroke engine whose cylinders act in direction of rotation of the cam 4. The mechanism comprises a regulator 44 of centrifugal type, shown in details on fig. 26 including fingers 51 of primary shaft 43, active weights 52, fingers 53 of secondary shaft 45 and springs 54. The working shaft 1 is connected fixedly to the primary shaft 43 through the fingers 51. The fingers 51 are in movable connection with grooves of suitable profile at the active weights 52, in this case two numbers, which are connected with the secondary hollow shaft 45 through the fixedly connected with them fingers 53. The fingers 51 and 53 are connected through calibrated springs 54. This way, when the engine rests or works with turnovers minimum resistible and similar to them, the active weights 52 are near to the secondary hollow shaft 45. The primary shaft 43 and the secondary hollow shaft 45 are quiet one another and are rotating with the turnovers of the working shaft 1. On increasing the engine's turnovers the active weights 52 distance from the axis influenced by the centrifugal forces until reaching the casing 55 of the secondary hollow shaft 45. The fingers 51 move through the profile grooves of the active weights 52 and the distance between fingers 51 and 53 diminishes, the result is overcoming the resistance of springs 54 and additional rotation of the secondary shaft 45 towards the primary shaft 43 in direction of rotation. The cam block 46, connected with the shaft 45 changes its initial position towards the maximums and the minimums of the working curve of the cam 4. On fig. 27a-c is shown a version of regulator 44' of mechanism with retarding phase shift for the engine from fig. 1. The springs 54' of this regulator connect the active weights 52' with each other and one of their ends joins fingers 53' of the secondary shaft 45. On increasing the turnovers above definite number the weights 52' move away overcoming the resistance of springs 54'. Fingers 51' of the primary shaft 43 slip over the profile grooves of the active weights 52' and distance between fingers 51' and 53' increases. This results in retarded rotation of the secondary shaft 45 towards the primary shaft 43 in direction of rotation and retarded phases of fuel-air mixture distribution. On fig. 28 is shown

gives the possibility of changing its clearance and component according to the needs. The distributive shafts 61 can serve also for driving of different units and aggregates of the engine. This engine certainly can be executed without mechanism regulating the fuel-air mixture distribution.

The cam engine according to the invention can be also executed as two-stroke engine. Such an example is shown on fig. 36 and 37. It is possible for the cylinder block in which are located the cylindrical sleeves 64 of the working cylinders 2 to be formed with upper 65 and bottom 66 sectors, in each sector 65 and 66 radial cavities are formed, corresponding to 67 and 68 for circulation of the cooling liquid. The cylindrical block can be executed as monolithic or component. A hermetic space 69 is formed round each cylinder 2 in the upper sector 65 of the cylinder block connected through blowing-down windows 70 with the working chamber of the cylinder 2. The windows 70 are formed in each cylindrical sleeve 64. In the space 69 which is continuously supplied from compressor, for example built in the engine, with fresh working substance, for example air, is created overpressure, necessary to clean the chamber from the combustion products. Discharging valves 72 are located in the cylinder head 71 to guide the combustion gases. The piston 3 is preferably to be with an additional seal 73 to prevent the leakage of fresh working substance into the space 69. Such an engine can be executed with one-side located cylinders including each of the above mentioned mechanisms. In comparison with the known two-stroke crank-rocker engines the described two-stroke cam engine whose cam is executed with curve according to the invention is more effective having similar thermodynamic cycle as shown on fig. 38b in comparison with fig. 38a.

The cam engine according to the invention can also be executed with Stirling cycle /see fig. 39 and 40/. On fig. 39 is shown such an engine with two equal cams 4C and 4D, located on the working shaft 1, turned to each other with their rectilinear horizontal sectors and dephased opposite one another under definite angle. The angle of dephasing is preferably to be round angle γ where is realized each sector of the curve /fig. 42 and 43/. As shown on fig. 41 the working curve of each cam 4C and 4D is executed as periodical curve having period θ and the number of periods is more than one. As shown on the figures each period consists of three sectors, realizing itself within the angle γ. The sectors are ascending, rectilinear horizontal and descending, all with equal size and the horizontal rectilinear sectors included only in one-side located convexities of the curve. The curve of each cam can respond to the regulations for equal accelerations of the followers 5 which are equidistant from the beginning and/or the middle of each ascending and descending sector. It is preferably the followers 5 of each equalized group of followers 5 to be with equal mass and located steadily round the axis of the cams. Their number round each cam is divisible to the sector's number of the curve. For example round cam with two periods and six sectors can be located six, twelve or eighteen etc. followers 5. This way is achieved maximum balance as to the engine as a whole,

works with more effective thermodynamic cycle /fig. 44b/ than the classic Stirling cycle /fig. 44a/. The effect of the additional dephasing on the thermodynamic cycle is shown on fig. 44c. The better efficiency in this case is due to the compression or the expansion of the working substance which is realized almost entirely in the zones, where heat is removed or accepted and the acceptance or the removing of heat between the regenerator 86 and the working substance is realized almost in constant volume.

One other possible embodiment of effective, balanced, steadily working and easily regulated engine with Stirling cycle is shown on fig. 40. This engine works with one cam 4 and as shown on the figure, the cylinders 2E and 2F for constantly low and constantly high temperature are located steadily side by side and the next cylinder but one round the axis of the engine. The central angle between the axis of two adjacent cylinders 2E and 2F from different type is equal to the angle γ of a sector from the cam's curve. The spaces above the pistons of each two cylinders 2E and 2F located one another under angle γ, are connected through regenerator /not shown on the figure/.

In these cases the mounting of the combustion chamber with the engines of Stirling type between the cylinders with constant high temperature results in considerable decrease of the clearance and the number of details of the engine. Besides, the losses of effective heat are less.

The shown examples serve only for illustration and do not limit the scope of the invention, which is determined only by the following claims.

7. Cam engine according to claims 3 and 5 characterized by the fact that in each convexity of the curve of the cam /4/ there is horizontal rectilinear sector and in the middle of each ascending and descending sector of the curve is with rectilinear inclined sectors and the accelerations of the followers /5/ on their movement through all rectilinear sectors are equal to zero.

8. Cam engine according to claim 6, characterized by the fact that the rectilinear horizontal sectors of the curve of the cam /4/ are with equal duration at the same angles of rotation of the cam /4/.

9. Cam engine according to claim 6, characterized by the fact that the rectilinear horizontal sectors are included in one-side located convexities on the curve of the cam /4/ and the ascending, the descending and the horizontal rectilinear sectors of each period located between them are with equal duration at the same angles of rotation of the cam /4/.

10. Cam engine according to claim 1, characterized by the fact that the followers /5/ form at least one balanced group of followers /5/ with equal mass or are assembled in units /5''/ which are all with equal number of followers /5/ located equidistant one another and form at least one balanced group of units /5''/ with equal mass.

11. Cam engine according to claims 2 and 3 characterized by the fact that:

a) the number of convexities of the curve of the cam /4/ is even and not less than four and these convexities are steadily located round the cam /4/;

b) the followers /5/ from each balanced group are steadily located round the axis of the cam /4/ and their masses are equal;

c) the number of the followers /5/ is even, and

d) the number of the convexities from the curve of the cam /4/ is divisible to the number of the followers /5/ and half the number of the convexities is odd.

12. Cam engine according to claims 2 and 3 characterized by the fact that:

a) the number of the curve's convexities is even and not less than four and these convexities are steadily located round the axis of the cam /4/;

b) the followers /5/ of each balanced group are steadily located round the axis of the cam /4/ and their masses are equal;

c) the number of the followers /5/ is divisible to four, and

d) half number of the curve's convexities is even but not divisible to the number of the followers /5/.

13. Cam engine according to claim 9 characterized by the fact that the number of the periods from the curve of the cam /4/ is more than one and number of the followers /5/ steadily located round each cam /4/ is divisible to the number of all descending, ascending and horizontal rectilinear sectors from the curve.

prolongation of the shaft /1/, secondary hollow shaft /45/ located round the primary shaft /43/, with the possibility of axial and/or angle displacement of the secondary hollow shaft /45/, and coaxial regulator /44/ for axial and angle displacement of the secondary hollow shaft /45/, coaxial cam block /46/ controlling the means for delivery /50/ and removal /48/ and connected with the hollow shaft /45/ with possibility for axial displacement through a splined connection.

24. Cam engine according to claim 23 characterized by the fact that the regulator /44/ is from centrifugal type.

25. Cam engine according to claim 23 characterized by the fact that the regulator /44/ is double operating hydraulic cylinder for axial movement of the hollow shaft /45/ and the splined connection between the cam block /46/ and the hollow shaft /45/ has slot inclined towards the axis.

26. Cam engine according to claim 23 characterized by the fact that further comprises a reversible block /56/ to turn the direction of rotation of the primary shaft /43/.

27. Cam engine according to claim 26 characterized by the fact that the reversible block /56/ is located between the regulator /44/ and the cam block /46/, and conical gears /60A, 60B/ which are coupled and coaxial towards the distributive shafts /61A, 61B/ where is located at least one cam /63/ controlling at least one means for removal /50/.

28. Cam engine according to claim 1 characterized by the fact that further comprises elements for removal /72/ of the working substance as the cylindrical block where are located cylindrical sleeves /64/ of the cylinders /2/ formed with upper /65/ and bottom /66/ sectors, in each of them formed cavities /67, 68/ for circulation of the cooling liquid and hermetic space /69/ is formed in the upper sector /65/, near to the bottom sector /66/ round each cylinder /2/, supplied with working substance of overpressure connected with the working chamber of the cylinder /2/ through blowing windows /70/ of each cylindrical sleeve /64/.

29. Cam engine according to claim 1, characterized by the fact that the contact surfaces /13, 13''/ from the cam /4/ are executed as per different functions with different stroke or with different phases of the strokes, or with different stroke and different phases of the strokes.

30. Cam engine according to claim 23, characterized by the fact that the cam block /46/ controlling the means for delivery /50/ and removal /48/ is executed component of coaxial parts in such a way that at least one part is connected to the primary shaft /43/ with possibility for angle displacement through a splined connection.

31. Cam engine according to claim 9, characterized by the fact that the axial cylinders /2/ are at least two, one cylinder /2C or 2F/ for constantly high and correspondent cylinder /2D or 2E/ for constantly low temperature, the spaces above the pistons connected to a regenerator /86/ and the spaces above pistons of the cylinders /2C and 2F/ for constantly high temperature connected to a combustible chamber /82/ located between them and provided

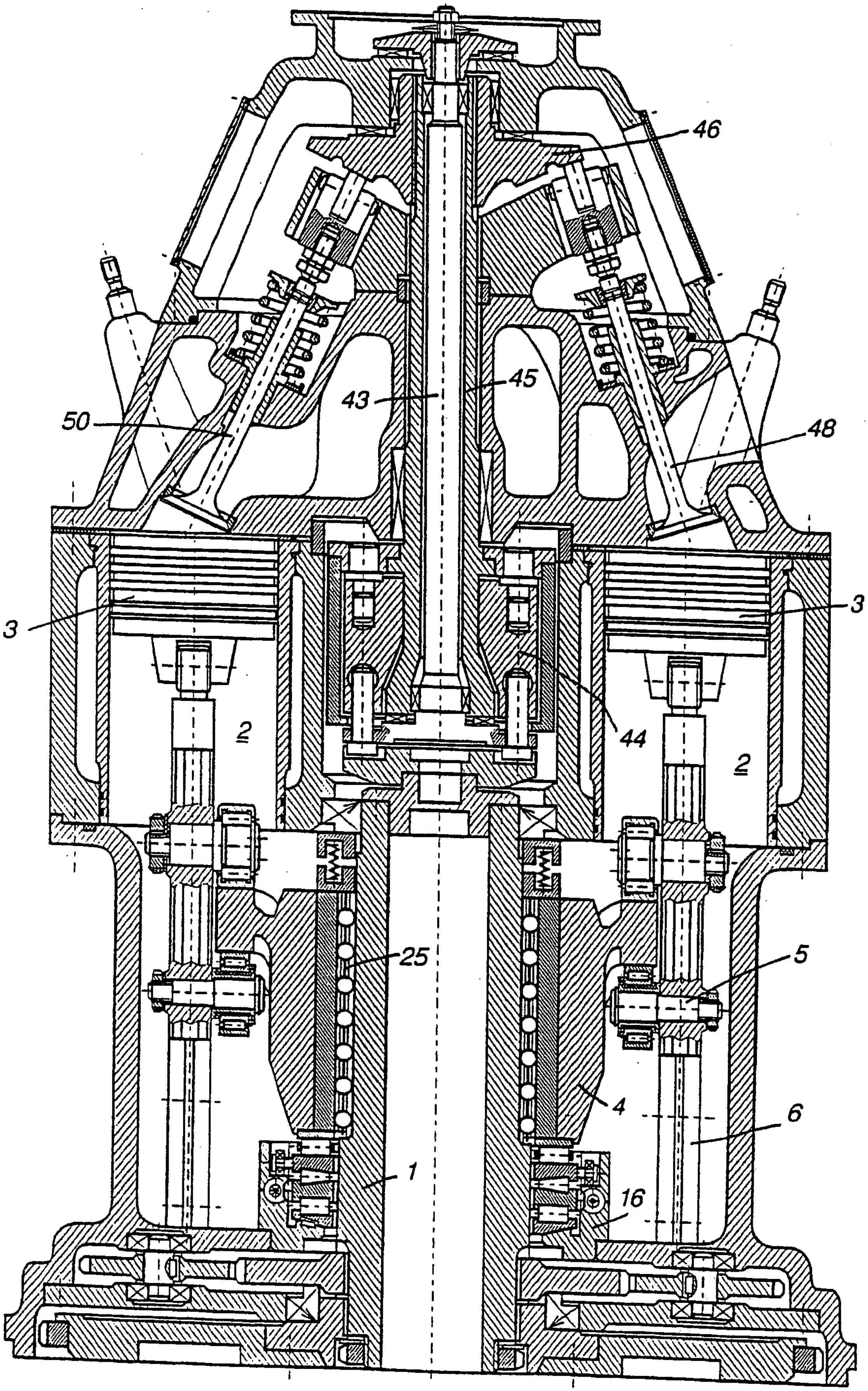


Fig. 1

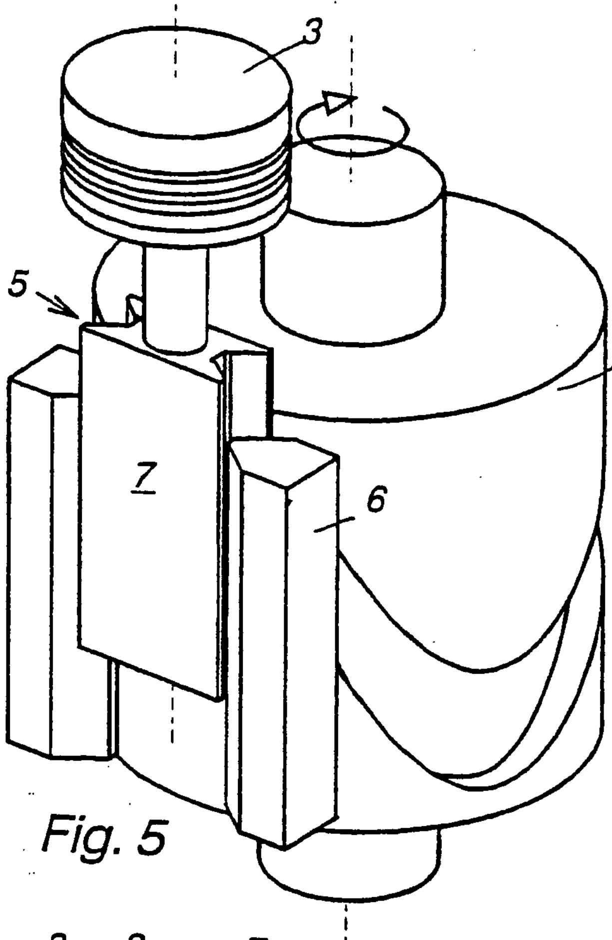


Fig. 5

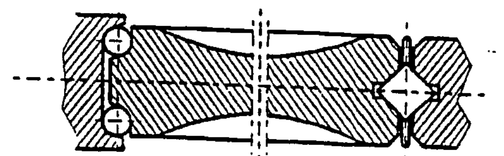


Fig. 7a Fig. 7b

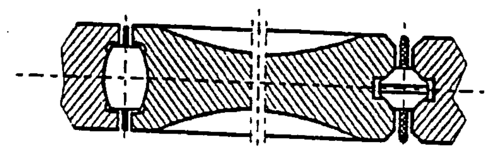


Fig. 7c Fig. 7d

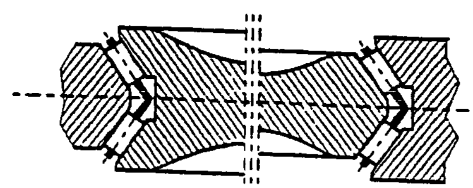


Fig. 7e Fig. 7f

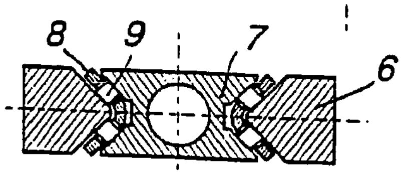


Fig. 6b

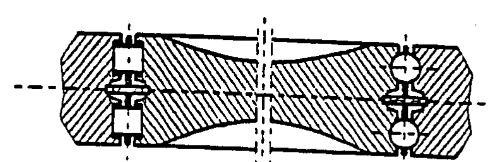


Fig. 7g Fig. 7h

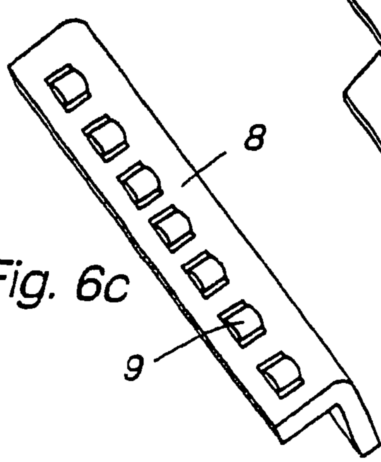


Fig. 6c

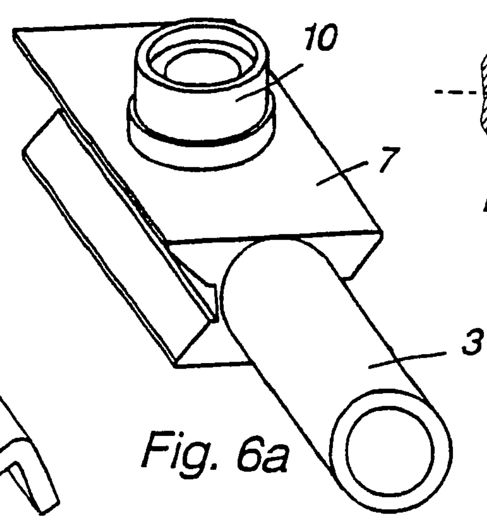


Fig. 6a

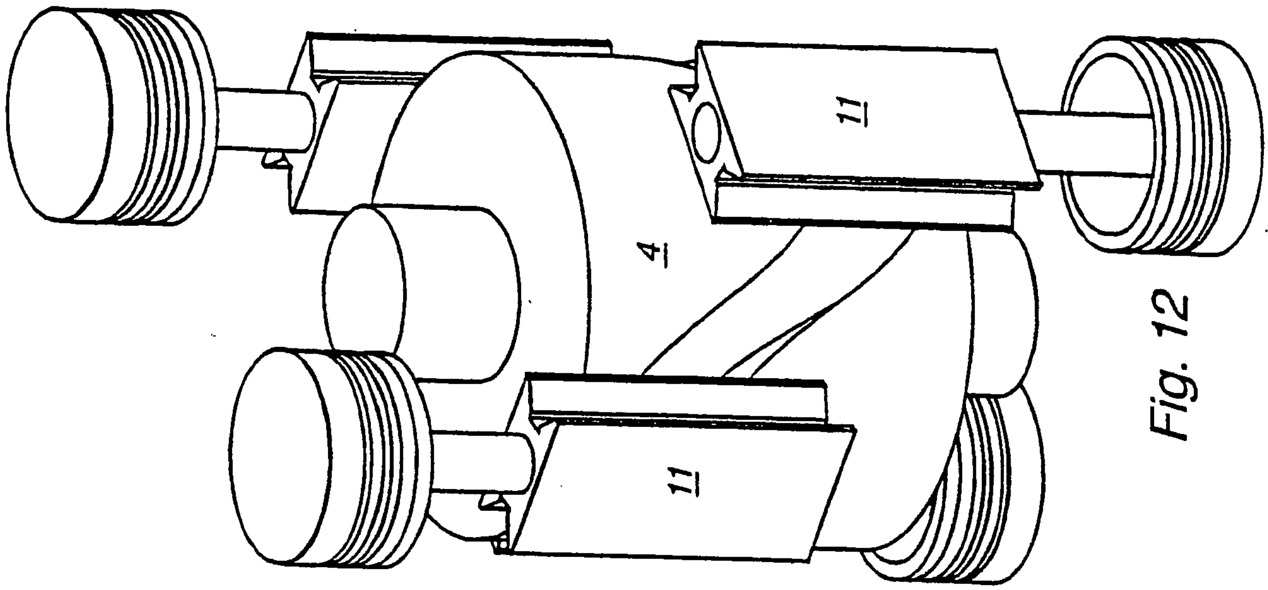


Fig. 12

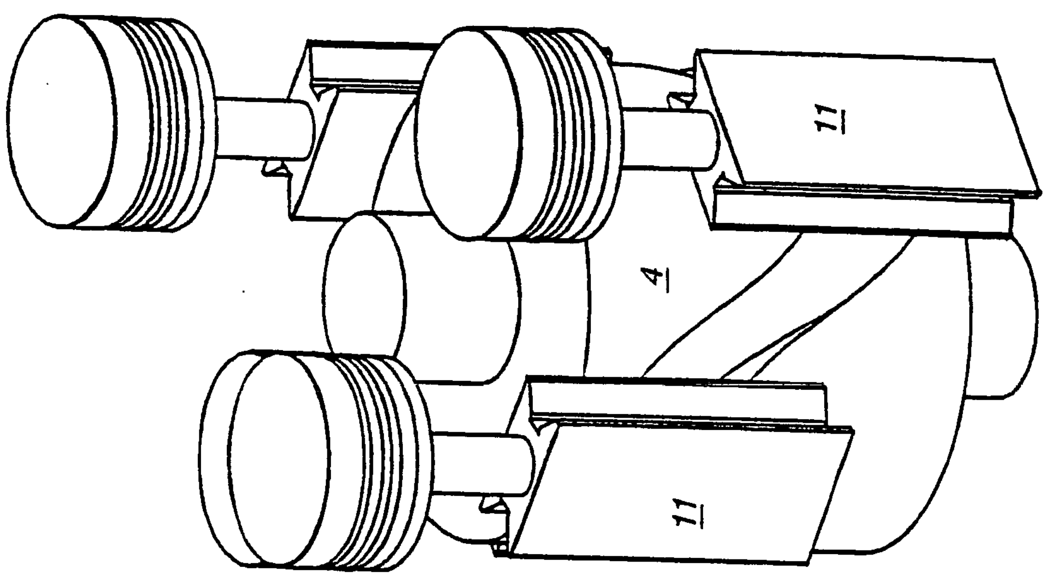


Fig. 11

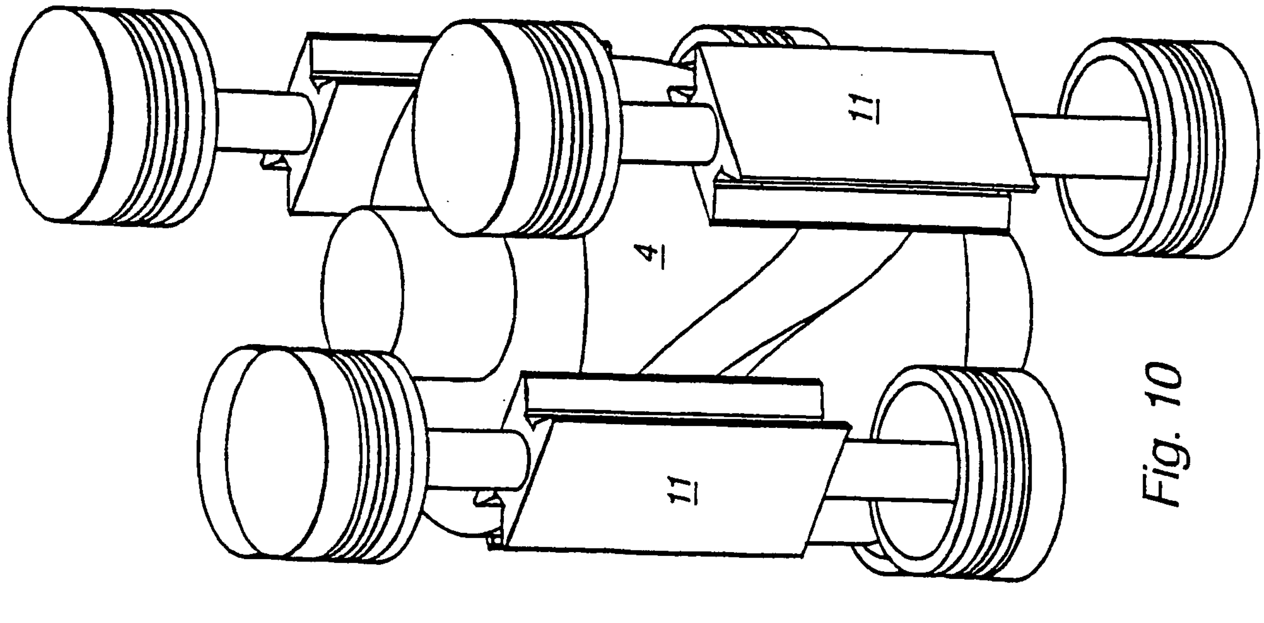


Fig. 10

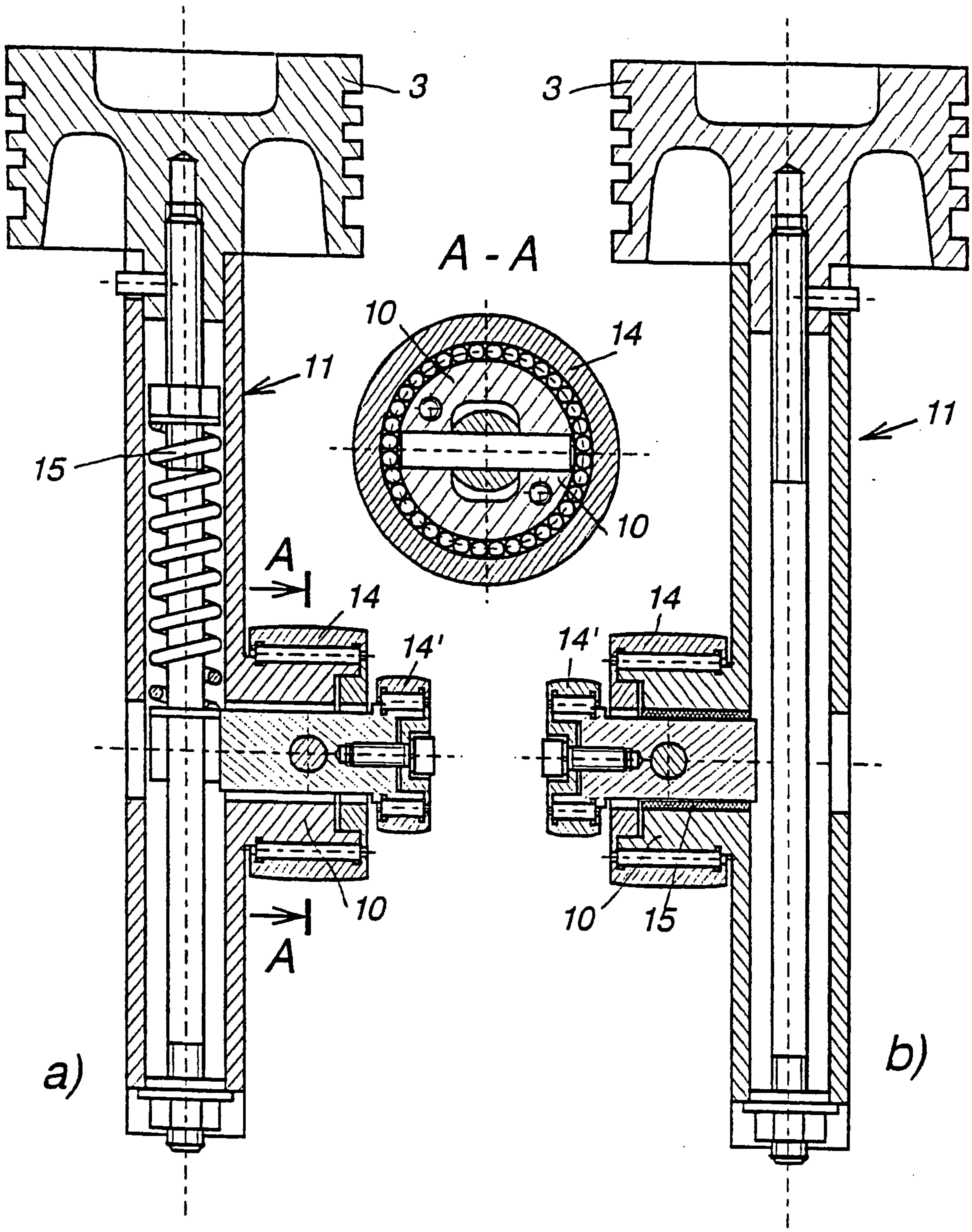


Fig. 16

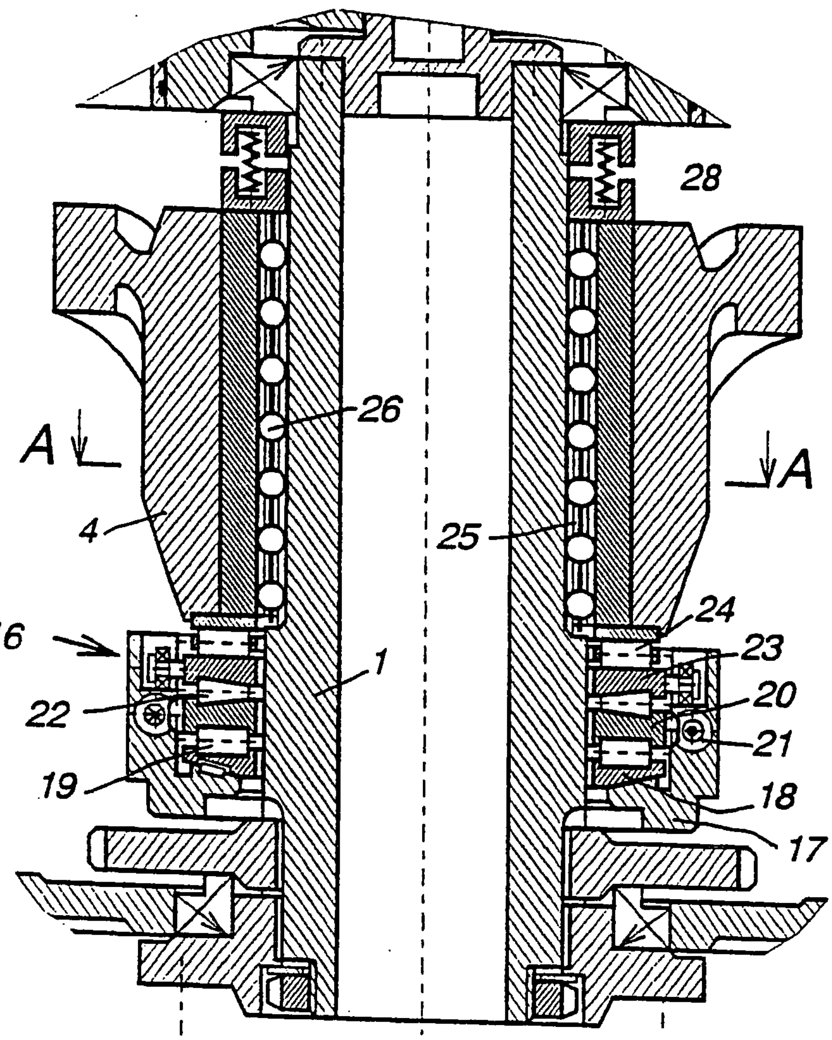


Fig. 19

A - A

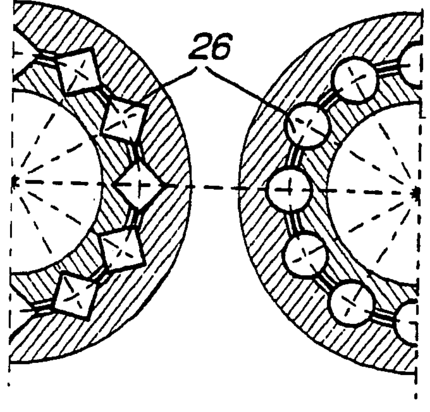


Fig. 21

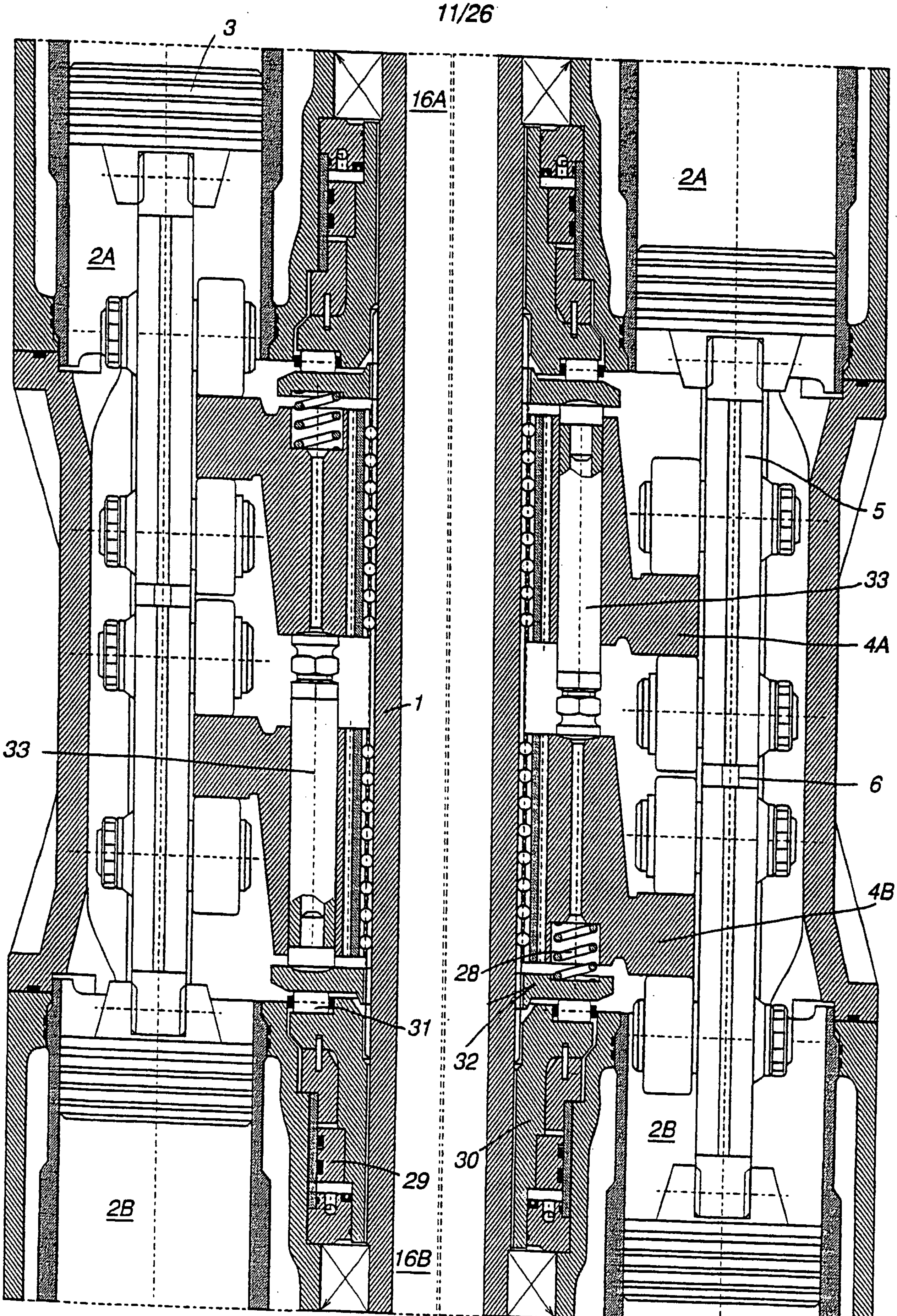


Fig. 23

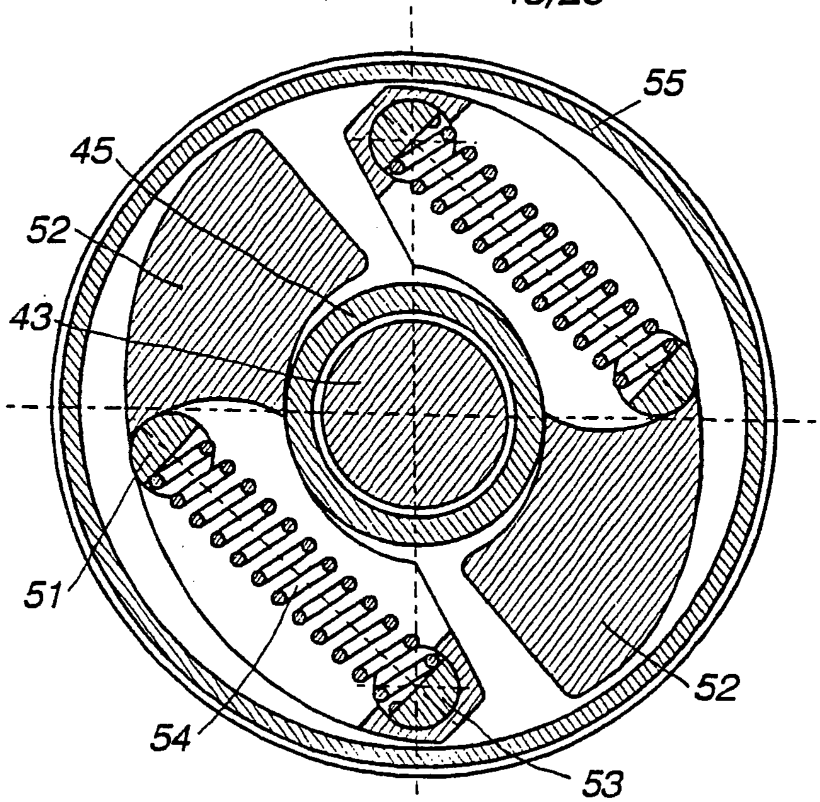


Fig. 26a

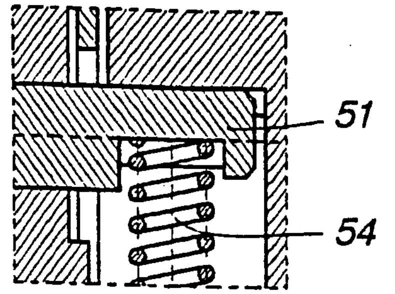


Fig. 26c

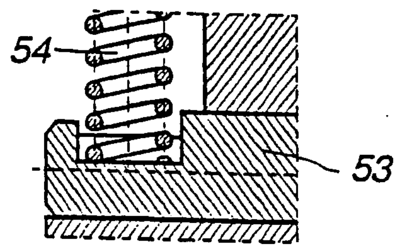


Fig. 26d

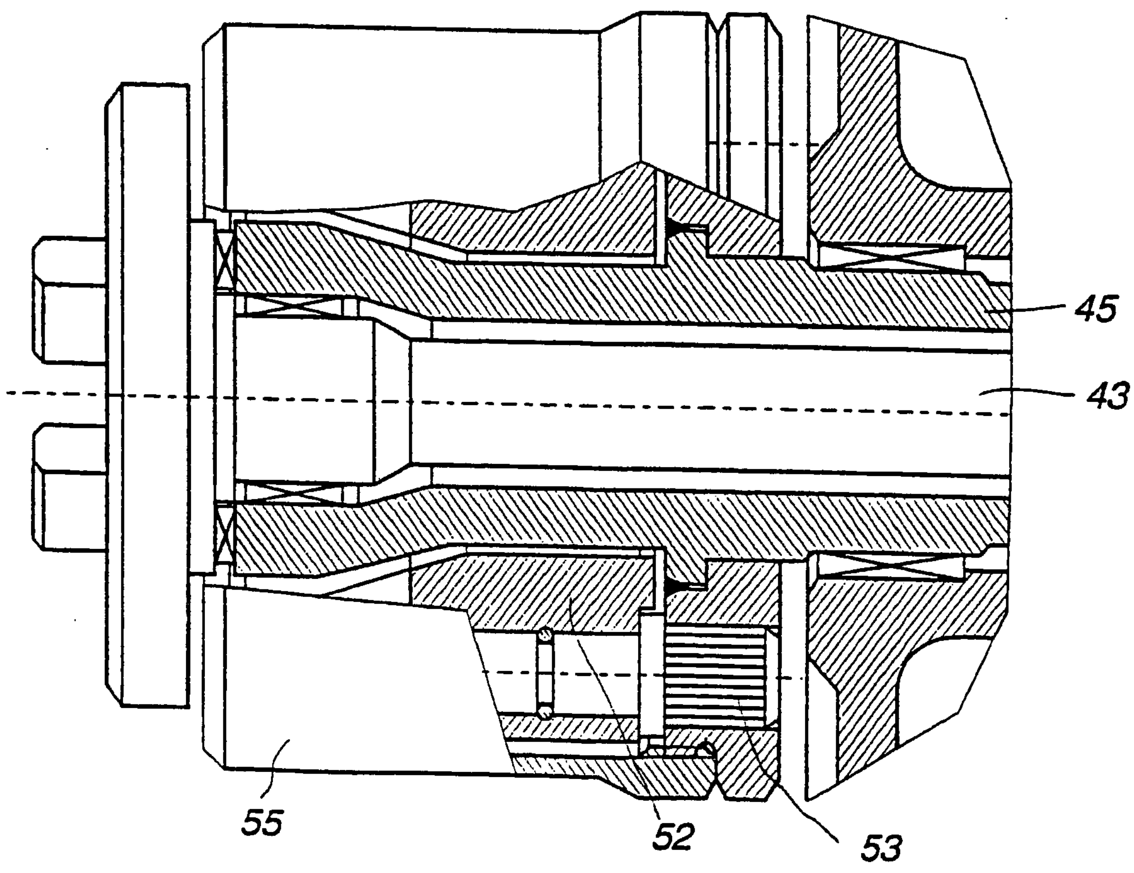


Fig. 26b

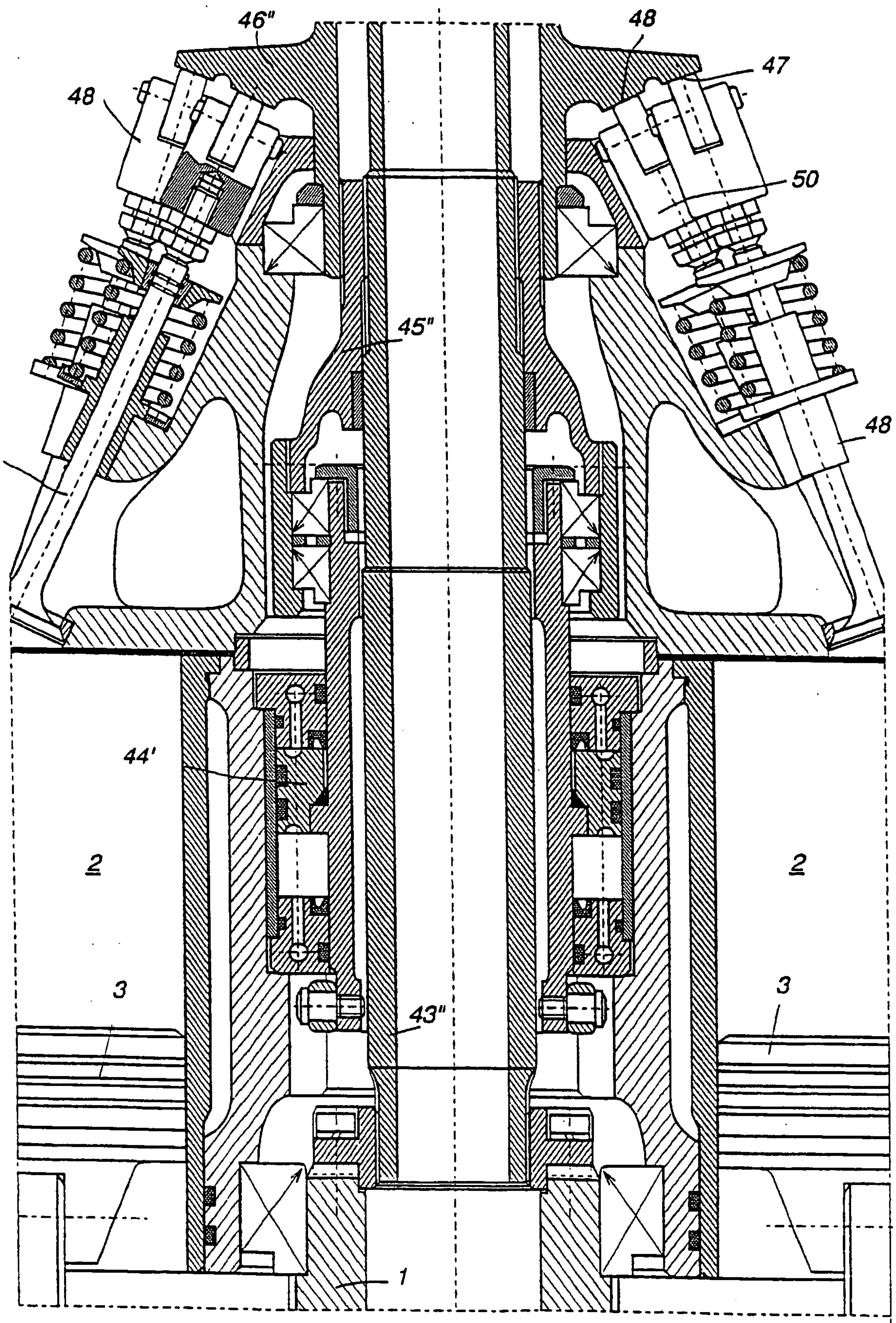


Fig. 28

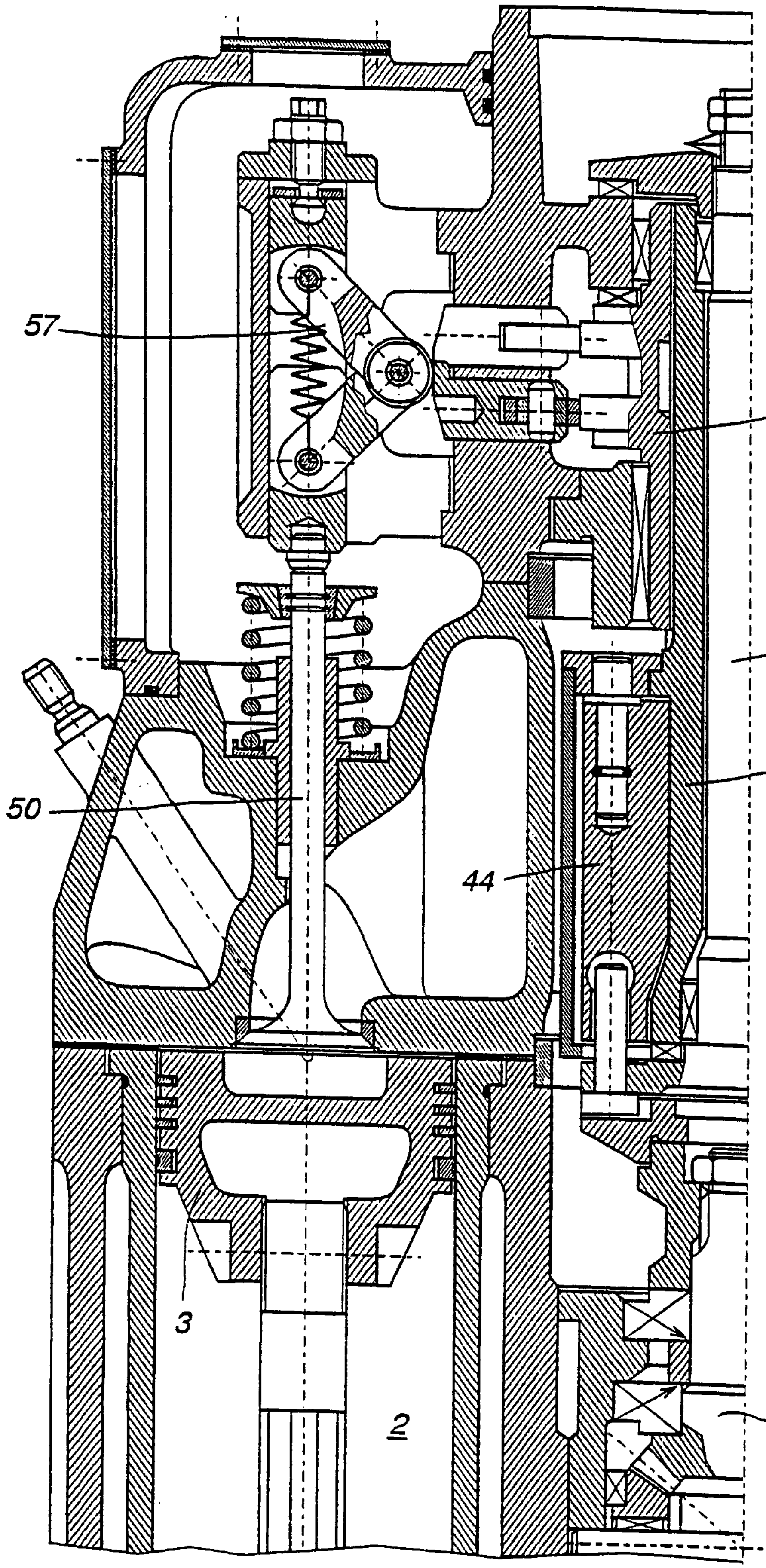
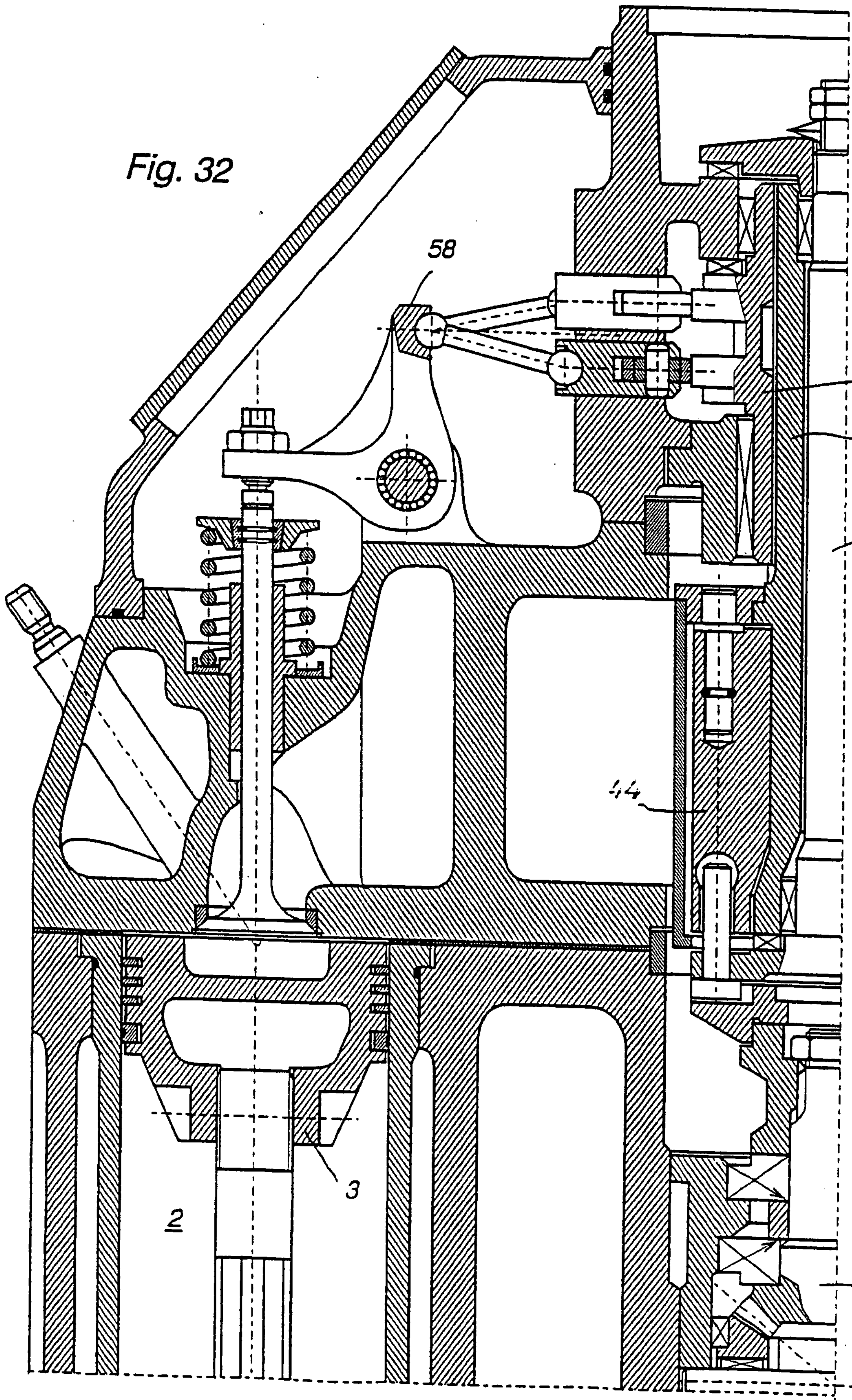


Fig. 30

Fig. 32



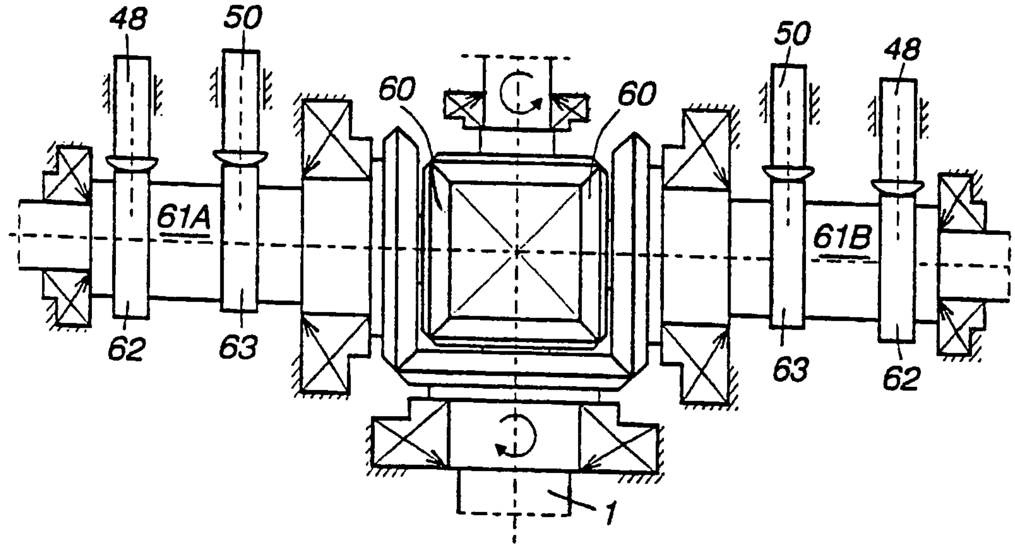


Fig. 35a

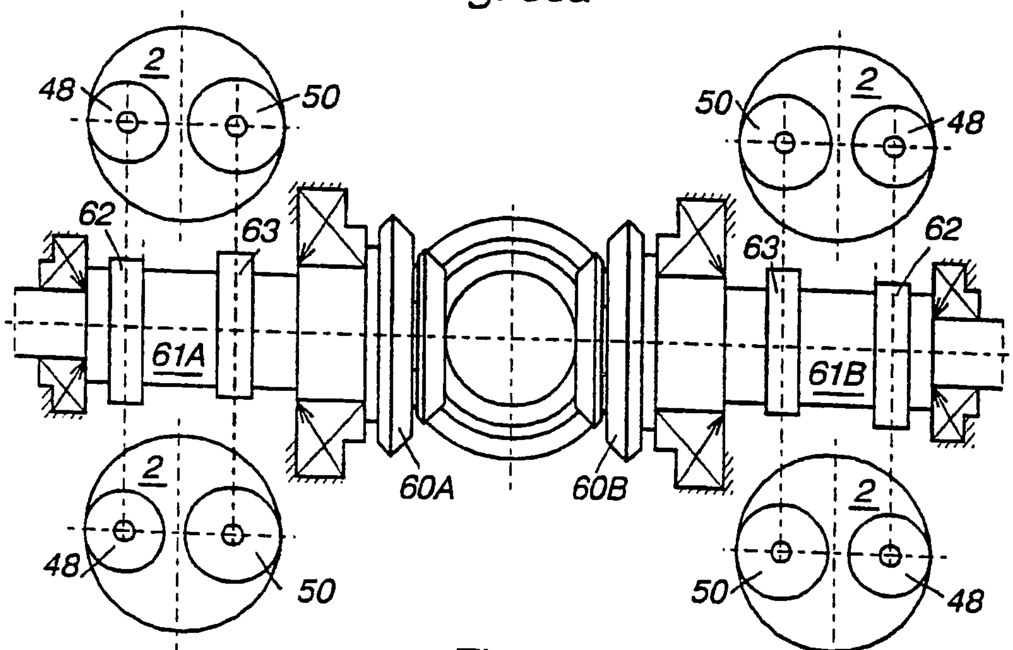


Fig. 35b

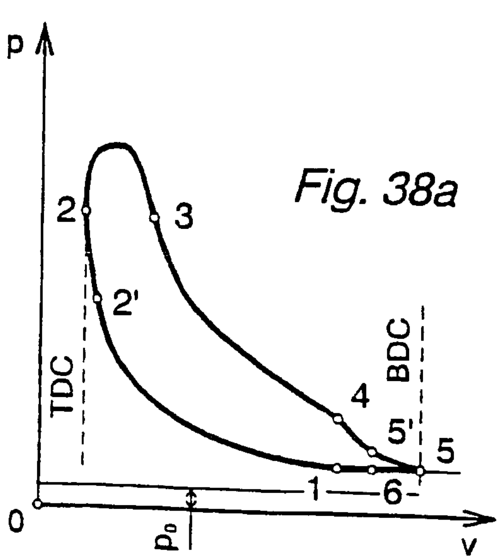


Fig. 38a

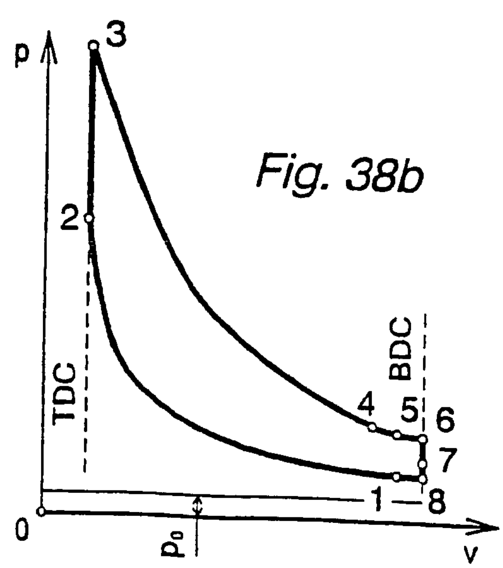


Fig. 38b

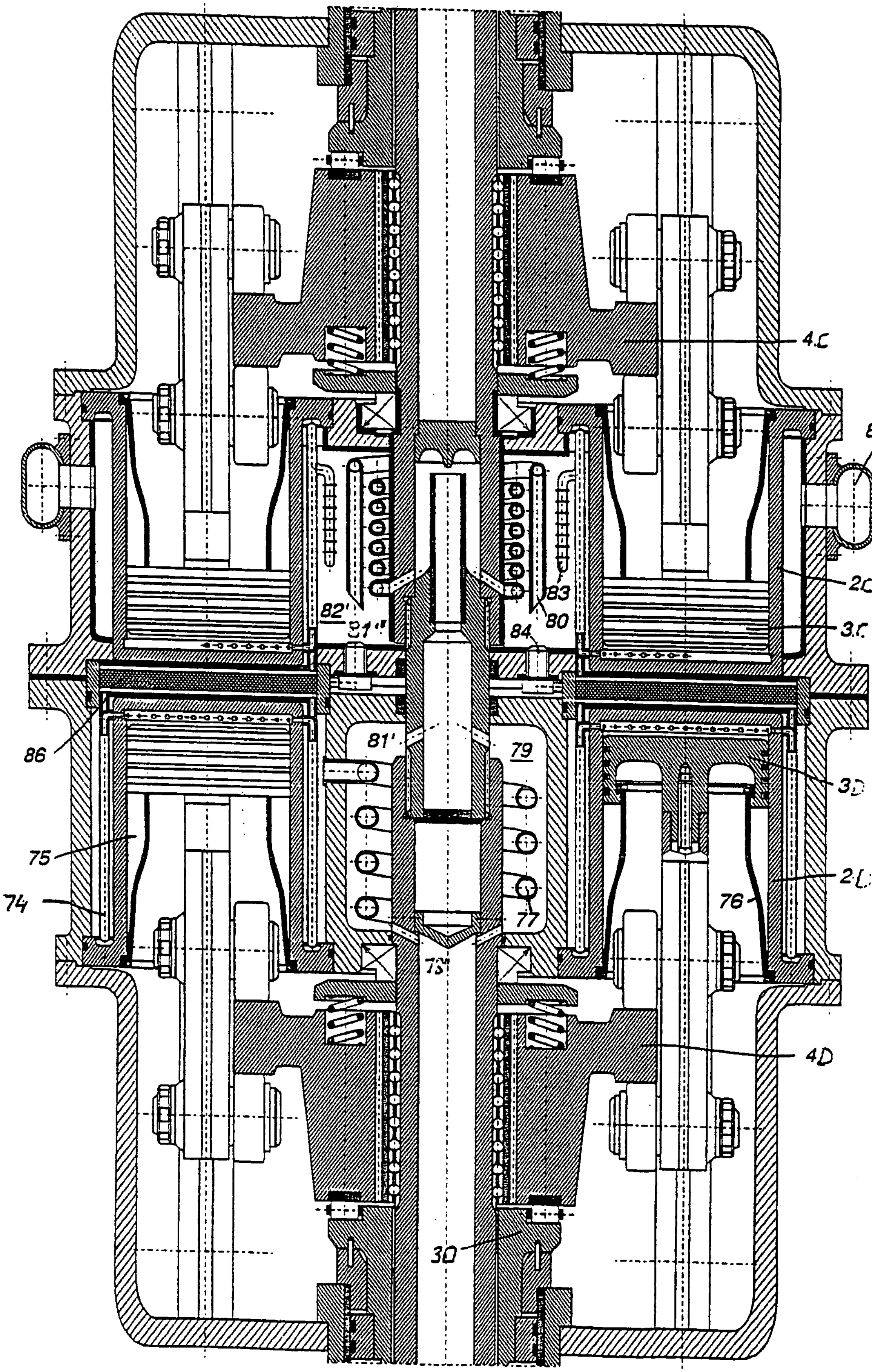


Fig. 39

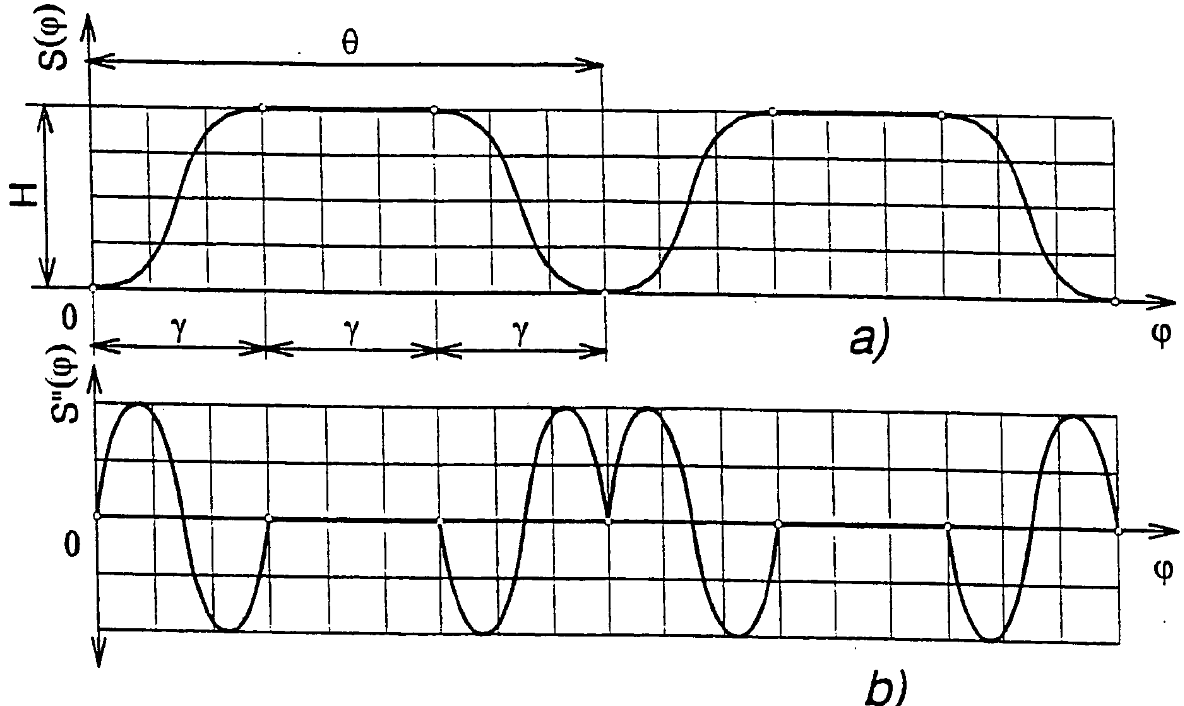

S(φ)
θ
H
0
γ
γ
γ
a)
φ
S''(φ)
0
φ
b)

Fig. 41

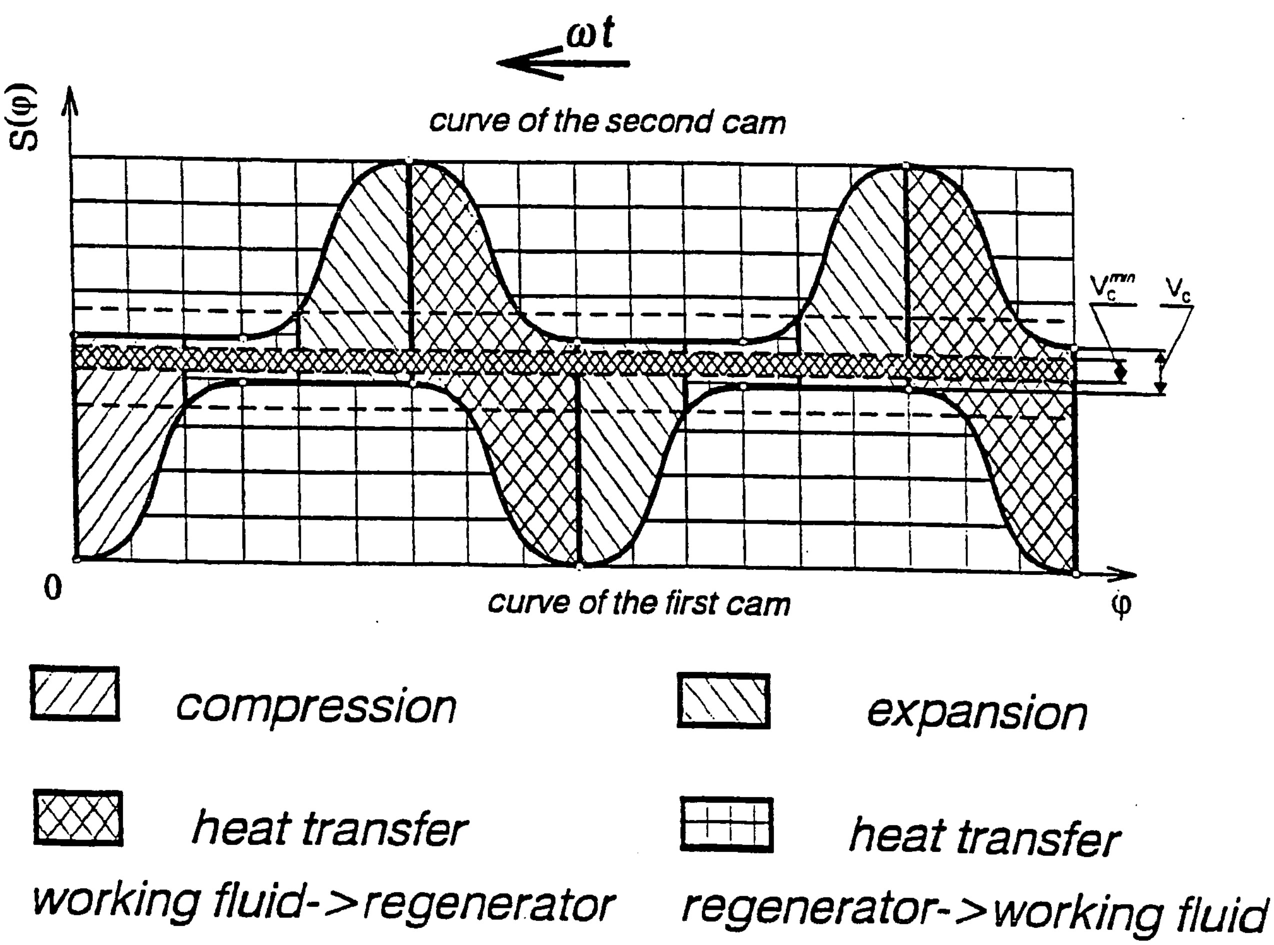

ωt
S(φ)
curve of the second cam
V_c^{min}
V_c
0
curve of the first cam
φ
compression
expansion
heat transfer
working fluid->regenerator
heat transfer
regenerator->working fluid

Fig. 42

INTERNATIONAL SEARCH REPORT

Inter. ...nal Application No
PCT/BG 97/00005

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F01B3/04 F02G1/044 F02B75/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F01B F02G F02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 88 05495 A (GEELONG ENGINE CO PTY LTD) 28 July 1988 see the whole document ---	1-5
X A	EP 0 137 621 A (DEMOPOULOS ANDREAS) 17 April 1985 see the whole document ---	1,6-9,13 10-12
X	US 4 996 953 A (BUCK ERIK S) 5 March 1991 see the whole document ---	1,5-9
A	WO 96 09465 A (LOWI ALVIN JR) 28 March 1996 see the whole document ---	1,19,29,32
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 1997	06.10.97

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Wassenaar, G

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter. ...nal Application No
PCT/BG 97/00005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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EP 0137621 A	17-04-85	GB 2145152 A JP 60069201 A	20-03-85 19-04-85
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